EUMETSAT Satellite Application Facility on Climate Monitoring

Product User Manual

Fundamental Climate Data Record of SSM/I Brightness Temperatures

CM-150 FCDR_SSMI

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1 The EUMETSAT SAF on Climate Monitoring

The importance of climate monitoring with satellites was recognized in 1999 by EUMETSAT Member States when they amended the EUMETSAT Convention to affirm that the EUMETSAT mandate is also to contribute to the operational monitoring of climate and the detection of global climatic changes". Following this, EUMETSAT established within its Satellite Application Facility (SAF) network a dedicated centre, the SAF on Climate Monitoring (CM SAF, http://www.cmsaf.eu). Since the start of the CM SAF in 1999 the project went through three phases, i.e., the Development Phase lasting from 1999 to 2004, the Initial Operations Phase (IOP) and the Continued Development and Operations Phase (CDOP). The consortium of CM SAF currently comprises the Deutscher Wetterdienst (DWD) as host institute, and the partners from the Royal Meteorological Institute of Belgium (RMIB), the Finnish Meteorological Institute (FMI), the Royal Meteorological Institute of the Netherlands (KNMI), the Swedish Meteorological and Hydrological Institute (SMHI) and the Meteorological Service of Switzerland (MeteoSwiss).

After focusing on the development of retrieval schemes to derive a subset of Essential Climate Variables (ECVs) in the development phase, CM SAF delivered to its users products based on Meteosat and polar orbiter data for Europe and Northern Africa supporting NMHSs in their provision of climate services in the IOP from 2004 to 2007. During CDOP, lasting from 2007 to 2012, the product validation continued, the time series were expanded and algorithms were further improved, while the study domain was extended from the baseline area to the MSG disk for the geostationary products and to include global and Arctic coverage for the polar orbiter products. In addition, long term climate datasets from polar orbiting and geostationary satellites are being generated for climate monitoring (i.e. HOAPS, METEOSAT and AVHRR-GAC based products).

A catalogue of available CM SAF products is available via the CM SAF webpage, http://www.cmsaf.eu/. Here, detailed information about product ordering, add-on tools, sample programs and documentation are provided.

2 Introduction

This CM SAF Product User Manual (PUM) provides information on the Fundamental Climate Data Record (FCDR) of Brightness Temperatures from the Special Sensor Microwave/Imager (SSM/I). The predecessors of this data record and the data processor suite have originally been developed at the Max-Planck Institute for Meteorology (MPI-M) and the University of Hamburg (UHH) for the Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data (HOAPS, http://www.hoaps.org/) climatology.

HOAPS is a compilation of climate data records for analysing the water cycle components over the global oceans derived from satellite observation (Andersson et al. 2011). The main satellite instrument employed to retrieve the geophysical parameters is the SSM/I and much work has been invested to process and carefully homogenize all SSM/I instruments onboard the Defence Meteorological Satellite Program (DMSP) platforms F08, F10, F11, F13, F14 and F15 (Andersson et al. 2010).

A technical description of the data sets including information on the file format as well as on the data access is provided in this document. Furthermore details on the implementation of the processing chain and individual processing steps are available in the Algorithm Theoretical Basis Document [RD 2]. Basic accuracy requirements are defined in the product requirements document [AD 2]. A detailed validation of the FCDR is available in the Validation report [RD 3].

2.1 Applicable documents

Reference	Title	Code
AD 1	Memorandum of Understanding between CM SAF and the Max-Planck Institute for Meteorology and Meteorological Institute, University of Hamburg	
AD 2	Cooperation Agreement	

2.2 Reference documents

Reference	Title	Code
RD 1	CM SAF Product Requirements Document	SAF/CM/DWD/PRD/1.6
RD 2	Algorithm Theoretical Basis Document Fundamental Climate Data Record of SSM/I Brightness Temperatures	SAF/CM/DWD/ATBD/FCDR_SSMI/1.0
RD 3	Validation Report Fundamental Climate Data Record of SSM/I Brightness Temperatures	SAF/CM/DWD/VAL/FCDR_SSMI/1.0

3 The SSM/I Instrument

SSM/I sensors have been carried aboard the DMSP satellite series since 1987. Up to three radiometers have been in orbit simultaneously. An extensive description of the instrument and satellite characteristics has been published by Hollinger (1987) and Wentz (1991). Hence, only a short summary of essential information is given here. The DMSP satellites operate in a near-circular, sun-synchronous orbit, with an inclination of 98.8° at an approximate altitude of 860 km. Each day, 14.1 orbits with a period of about 102 minutes are performed. The Earth's surface is sampled with a conical scan at a constant antenna boresight angle of 45° over an angular sector of 102.4° resulting in a 1400 km wide swath on the Earth surface (Figure 1). A nearly complete coverage of the Earth by one SSM/I instrument is achieved within two to three days. Due to the orbit inclination and swath width, the regions poleward of 87.5° are not covered.

To date, six SSM/I instruments have been successfully launched aboard the F08, F10, F11, F13, F14 and F15 spacecrafts. All satellites have a local equator crossing time between 5 and 10 A.M./P.M. for the descending/ascending node. The F08 had a reversed orbit with the ascending node in the morning. Also, the Earth observing angular sector of the scan on this satellite is, differently from the others, centred to the aft of the sub-satellite track. Most of the DMSP satellites have a stable orbit. The temporal variation of the equator crossing times is less than three hours for all satellites. At the end of the time period the orbits of F14 and F15 begin to decay noticeably, but are still within 2-3 hours of original time.

The SSM/I is a seven channel total power radiometer measuring emitted microwave radiation at four frequency intervals centred at 19.35, 22.235, 37.0, and 85.5 GHz. All frequencies are sampled at horizontal and vertical polarization, except for the 22.235 GHz channel, which measures only vertically polarized radiation. The channels will be referred to as 19, 22, 37, and 85 GHz hereafter and the corresponding brightness temperatures of each channel and polarization as TB19v/h, TB22v, TB37v/h, and TB85v/h.

The spatial resolution varies from 69 km by 43 km with a sampling frequency of 25 km for the 19 GHz channel to 15 km by 13 km with 12.5 km sampling frequency for the 85 GHz channel. The

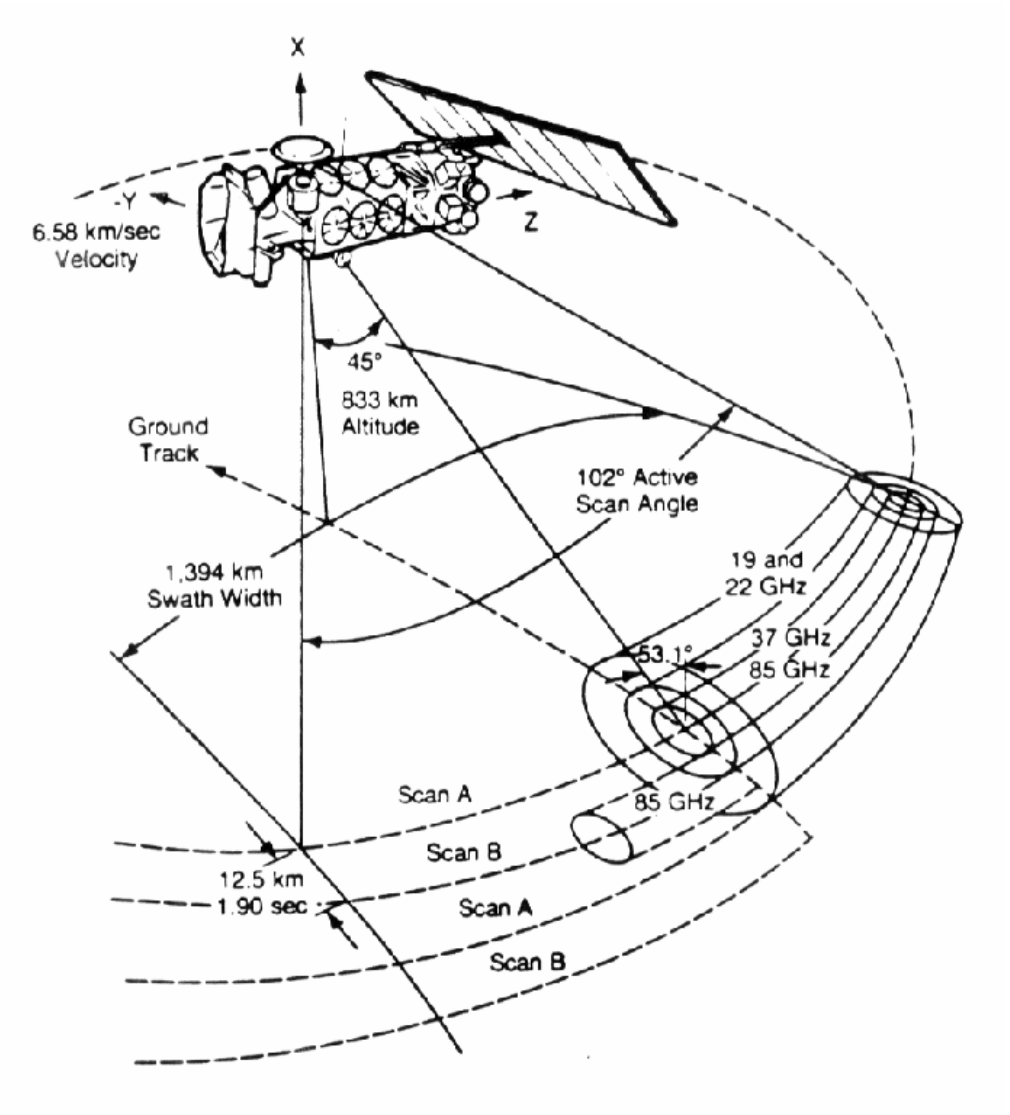

Figure 1: SSM/I scan geometry (from Hollinger et al., 1987).

85 GHz channels are sampled for each rotation of the instrument (A and B-scans) with a resolution of 128 uniformly spaced pixels, while the remaining channels are sampled every other scan (A-scans) with a resolution of 64 pixels (see Figure 1). A fixed cold space reflector and a reference black body hot load are used for continuous onboard two point calibration.

4 Product definition

The CM SAF FCDR from SSM/I brightness temperatures are compiled as daily collections of all observations from one sensor. All sensor specific data available in the raw data records are provided as well as additional information like quality control flags, Earths incidence angles, averaged 85 GHz brightness temperatures, incidence angle normalisation offsets and inter-sensor calibration offsets.

5 Data format description

The CM SAF FCDR dataset is provided as NetCDF (Network Common Data Format) files (http://www.unidata.ucar.edu/software/netcdf/). The data files are compiled following NetCDF

Climate and Forecast (CF) Metadata Convention version 1.5 (http://cf-pcmdi.llnl.gov/) and NetCDF Attribute Convention for Dataset Discovery version 1.0.

All SSM/I FCDR products files are swath based and built following the same design principles. The record dimension of the data files is the B-scan integer time measured in seconds since 1st January 1987. Each file contains all possible scans for one complete day (~ 22749 scans) regardless of their quality and status. Missing scans are marked as missing and sensor data are set to undefined in this case.

The users are advised to read and apply the supplied quality control flags *qc_scan*, *qc_channel*, *qc_fov_lo* and *qc_fov_hi* in order to filter incorrect and erroneous observations. The quality control procedure and thresholds are described in the ATBD [RD 2].

To account for the higher 85GHz channels sampling (see section 3), an additional dimension *scan_type* is used keeping the same record dimension as for the low resolution channels. This keeps the file format compatible to the original NOAA/NESDIS format and results in a 4-dimensional array for the 85GHz channel brightness temperatures: [*time*, *scan_type*, *channel_hifreq*, *across_track*]. The observation time of the A-scan can be calculated by subtracting 60/*rotation* (~1.9 s) from the B-scan time.

The FOV positions of the high and low resolution channels are co-registered. To get the FOV position of the lower resolution channel the *across_track_lores* coordinate variable can be used as an index to the A-scan position arrays:

lat_lores = *lat*[*time*, 0, *across_track_lores*]

This follows the CF convention for compression by gathering and the corresponding attribute *compress* is assigned to the coordinate variable *across_track_lores*.

Daily mean values have a fixed dimension *date* of size 1.

5.1 Data file contents

A common NetCDF file consists of dimensions, variables, and attributes. These components can be used together to capture the meaning of data and relations among data. Global attributes are summarized in Table 1 and possible variable attributes in Table 2 (Appendix A). The following variables (thematically sorted) are available in the FCDR data files:

Coordinate variables

date
: Validity date [days counted from 1987-01-01 00:00:00 UTC]
Fixed dimension [1]

time
: B-Scan start time [seconds counted from 1987-01-01 00:00:00 UTC]
Record dimension

across_track
: FOV across track position of high resolution channels
Fixed dimension [128]

across_track_lores
: FOV across track position of low resolution channels
Fixed dimension [64]
compress = *across_track*

channel
Channel number
Fixed dimension [7]

channel_hifreq
Channel number of high frequency channels
Fixed dimension [2]
compress = *channel*

Explanatory variables

channel_name
String representation of the corresponding channel number.
[“V19”, “H19”, “V22”, “V37”, “H37”, “V85”, “H85”]

scan_type_name
String representation of the corresponding scan type.
[“A”, “B”]

Daily mean statistical variables

rotation
instrument rotational speed [rpm]
dimension [*date*]

hotc_var
variance of hot load reading [count^2]
dimension [*date, channel*]

colc_var
variance of cold load reading [count^2]
dimension [*date, channel*]

trhl_var
variance of hot load temperature [K^2]
dimension [*date*]

nedt
noise equivalent temperature [K]
dimension [*date, channel*]

Quality control variables

qc_scan
Scanline quality control [bit mask]
dimension [*time*]
All bits set to 0 indicates normal condition.

qc_channel
Channel quality control [bit mask]
dimension [*time, channel*]
All bits set to 0 indicates normal condition.

qc_fov_lo
Field of view quality control, low-resolution [bit mask]
dimension [*time, across_track_lores*]
All bits set to 0 implies acceptable data.

qc_fov_hi
Field of view quality control, high-resolution [bit mask]
dimension [*time, across_track*]
All bits set to 0 implies acceptable data.

Geolocation variables

tfrac
B-scan micro seconds [10^-6 s]
dimension [*time*]
To get the exact scan time add this to *time*.

lat
FOV latitude [degree_north]
dimension [*time, scan_type, across_track*]

lon
FOV longitude [degree_east]
dimension [*time, scan_type, across_track*]

laz
FOV local azimuth angle [degree_east]
dimension [*time, across_track*]

sft_lo
FOV surface type for low resolution channels
dimension [*time, across_track_lores*]
Possible types are: water, land, coast, sea_ice, sea_ice_edge

sft_hi
FOV surface type for high resolution channels
dimension [*time, scan_type, across_track*]
Possible types are: water, land, coast, coast2, sea_ice, sea_ice_edge

rev
Revolution number
dimension [*time*]

salt
Altitude of spacecraft [km]
dimension [*time*]

slat
Latitude of spacecraft sub satellite point [degree_north]
dimension [*time*]

slon
Longitude of spacecraft sub satellite point [degree_east]
dimension [*time*]

eia
Earth incidence angle [degree]
dimension [*time*]

Calibration and sensor state variables

slope
Calibration slope [K/count]
dimension [*time, channel*]

offset
Calibration offset [K]
dimension [*time, channel*]

trhl
Hot load temperature [K]
dimension [*time, nread*]

trfr
Forward radiator temperature [K]
dimension [*time*]

trrf
R.F. mixer temperature [K]
dimension [*time*]

hotc
Hot load reading [count]
dimension [*time, scan_type, channel, nload*]

colc
Cold load reading [count]
dimension [*time, scan_type, channel, nload*]

rvolt
Reference voltage
dimension [*time, nread*]

agc
Automatic gain control setting
dimension [*time, scan_type, channel*]

md5
MD5 message digest
dimension [*time, ndigest*]

Sensor data variables

tb
Brightness temperature [K]
dimension [*time, channel, across_track_lores*]

ical
Brightness temperature intercalibration offset [K]
dimension [*time, channel, across_track_lores*]

eia_norm

Brightness temperature earth incidence angle normalization offset [K]
dimension [*time, channel, across_track_lores*]

tb_hi

Brightness temperature, 85GHz [K]
dimension [*time, scan_type, channel_hifreq, across_track*]

ical_hi

Brightness temperature intercalibration offset, 85GHz [K]
dimension [*time, scan_type, channel_hifreq, across_track*]

6 Data ordering via the Web User Interface (WUI)

User services are provided through the CM SAF homepage www.cmsaf.eu. The user service includes information and documentation about the CM SAF and the CM SAF products, information on how to contact the user help desk and allows to search the product catalogue and to order products.

On the main webpage, a detailed description how to use the web interface for product search and ordering is given. We refer the user to this description since it is the central and most up to date documentation. However, some of the key features and services are briefly described in the following sections.

Copyright note:
All intellectual property rights of the CM SAF products belong to EUMETSAT. The use of these products is granted to every interested user, free of charge. If you wish to use these products, EUMETSAT's copyright credit must be shown by displaying the words "copyright (year) EUMETSAT" on each of the products used

6.1 Product ordering process

You need to be registered and logged in to order products. A login is provided upon registration, all products are delivered free of charge. After the selection of the product, the desired way of data transfer can be chosen. This is either via a temporary ftp account (the default setting), or by CD/DVD or email. Each order will be confirmed via email, and the user will get another email once the data have been prepared. If the ftp data transfer was selected, this second email will provide the information on how to access the ftp server.

6.2 Contact User Help Desk staff

In case of questions the contact information of the User Help Desk (e-mail address contact.cmsaf@dwd.de, telephone and fax number) are available via the CM SAF main webpage (www.cmsaf.eu) or the main page of the Web User Interface.

6.3 Feedback/User Problem Report

Users of CM SAF products and services are encouraged to provide feedback on the CM SAF product and services to the CM SAF team. Users can either contact the User Help Desk (see chapter 6.2) or use the “User Problem Report” page. A link to the “User Problem Report” is available either from the CM SAF main page (www.cmsaf.eu) or the Web User Interface main page.

6.4 Service Messages / log of changes

Service messages and a log of changes are also accessible from the CM SAF main webpage (www.cmsaf.eu) and provide useful information on product status, versioning and known deficiencies.

7 References

Andersson, Axel; Bakan, Stephan; Fennig, Karsten; Grassl, Hartmut; Klepp, Christian-Phillip; Schulz, Joerg: Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data - HOAPS-3 - monthly mean., electronic publication, World Data Center for Climate, doi:10.1594/WDCC/HOAPS3_MONTHLY, 2007a.

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Andersson, A., Fennig, K., Klepp, C., Bakan, S., Graßl, H., and Schulz, J.: The Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data – HOAPS-3, Earth Syst. Sci. Data, 2, 215-234, doi:10.5194/essd-2-215-2010, 2010.

8 Glossary

ATBD	Algorithm Theoretical Baseline Document
CM SAF	Satellite Application Facility on Climate Monitoring
DMSP	Defense Meteorological Satellite Program
DWD	Deutscher Wetterdienst (German MetService)
ECV	Essential Climate Variable
EIA	Earth Incidence Angle
EPS	European Polar System
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FCDR	Fundamental Climate Data Record
FMI	Finnish Meteorological Institute
FOV	Field of view
GCOS	Global Climate Observing System
GLOBE	The Global Land One-kilometer Base Elevation
HOAPS	The Hamburg Ocean Atmosphere Fluxes and Parameters from Satellite data
IOP	Initial Operations Phase
KNMI	Koninklijk Nederlands Meteorologisch Institut
MSG	Meteosat Second Generation
NASA	National Aeronautics and Space Administration
NESDIS	National Environmental Satellite, Data, and Information System
NOAA	National Oceanic & Atmospheric Administration
PRD	Product Requirement Document
PUM	Product User Manual
QC	Quality Control
RMIB	Royal Meteorological Institute of Belgium
SAF	Satellite Application Facility
SMHI	Swedish Meteorological and Hydrological Institute
SSM/I	Special Sensor Microwave Imager
SSMIS	Special Sensor Microwave Imager Sounder
TA	Antenna Temperature
TB	Brightness Temperature
TDR	Temperature Data Records

9 Appendix A

Table 1: Global NetCDF attributes.

Name	Description
title	dataset title
summary	short description of the data file content
Conventions	conventions followed, "CF-1.5" for all files
Metadata_Convention	conventions followed, "Unidata Dataset Discovery v1.0" for all files
netcdf_library_version	NetCDF library version used
institution	institution where the data was produced
creator_url	URL contact information for the creator of the data
creator_email	email contact information for the creator of the data
references	references that describe the data or methods used to produce it
source	original data source
cdm_data_type	data type, “swath” for all files
filename	original filename
time_coverage_start	temporal coverage start of the data [ISO8601 date]
time_coverage_end	temporal coverage end of the data [ISO8601 date]
geospatial_lat_units	latitude attributes unit
geospatial_lat_min	latitude bounding box minimum
geospatial_lat_max	latitude bounding box maximum
geospatial_lon_units	longitude attributes unit
geospatial_lon_min	longitude bounding box minimum
geospatial_lon_max	longitude bounding box maximum
revolution_coverage_start	revolution coverage start of the data [revolution since launch]
revolution_coverage_end	evolution coverage end of the data [revolution since launch]
satellite_name	spacecraft name [e.g. “DMSP-F13”]
satellite_id	spacecraft number [e.g. 13]
instrument_name	instrument name, “SSM/I”
scanlines_count	total number of scan-lines in the data file
scanlines_missing_count	number of missing scan-lines in the data file
scanlines_coverage_percent	fraction of available scans in the data file
dataset_version	FCDR version number
date_created	date on which the data was created [ISO8601 date]
date_modified	date on which the data was modified [ISO8601 date]
history	provides an audit trail for modifications to the original data

Table 2: Attributes assigned to variables.

Name	Description
long_name	long descriptive name
standard_name	standard name that references a description of a variable's content in the CF standard name table
units	physical unit [udunits standards]
C_format	format string that should be used for C applications to print values for this variable, applies to the scaled (internal) type and value
FORTRAN_format	format string that should be used for FORTRAN applications to print values for this variable, applies to the scaled (internal) type and value
valid_min	smallest valid value of a variable
valid_max	largest valid value of a variable
scale_factor	The data are to be multiplied by this factor after it is read.
add_offset	This number is to be added to the data after it is read. If scale_factor is present, the data are first scaled before the offset is added.
_FillValue	This number represent missing or undefined data. Missing values are to be filtered before scaling.
flag_masks	list of bit fields expressing Boolean or enumerated flags
flag_meanings	descriptive words for each flag value
cbtf_parameter_id	unique internal parameter ID
compress	Records dimensions which have been compressed by gathering.